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WORKSHEETS
ATTEMPT CHECK CORRECT IMPROVE

OCR A A Level Physics | Kinetic and gravitational potential energy

35-40 minutes independent practice + 15-20 minutes review | 40 marks

Specification points covered

- 3.3.2(a) Define and calculate kinetic energy, $E_k = ½mv^2$, and derive it from first principles.
- 3.3.2(b) Define and calculate gravitational potential energy, $E_p = mgh$, and derive it from first principles.
- 3.3.2(c) Explain the exchange between gravitational potential energy and kinetic energy.

Mission assumptions
Project Asteria is an asteroid-deflection and sample-return mission. For every stated height change, treat the gravitational field strength as uniform at $g = 0.24\ N\ kg^{-1}$. Show numerical working in blank spaces; use the ruled lines for precise explanations.

1. Deriving the equations from first principles [7 marks]

The mission team checks that its energy model follows from earlier mechanics rather than treating the equations as facts to memorise.

(a) Starting with $W = Fs$, $F = ma$ and $v^2 = u^2 + 2as$, derive $\Delta E_k = ½m(v^2 - u^2)$. Show every algebraic step. **[4 marks]**

(b) A payload is raised slowly through a vertical height Δh so that its speed stays constant. Starting with $W = Fs$ and the weight mg, derive $\Delta E_p = mg\Delta h$. Explain why the work done increases the gravitational potential energy store. **[3 marks]**

2. Calibration calculations [5 marks]

Before descent, three systems are checked close to the asteroid surface. Use g = 0.24 N kg⁻¹.

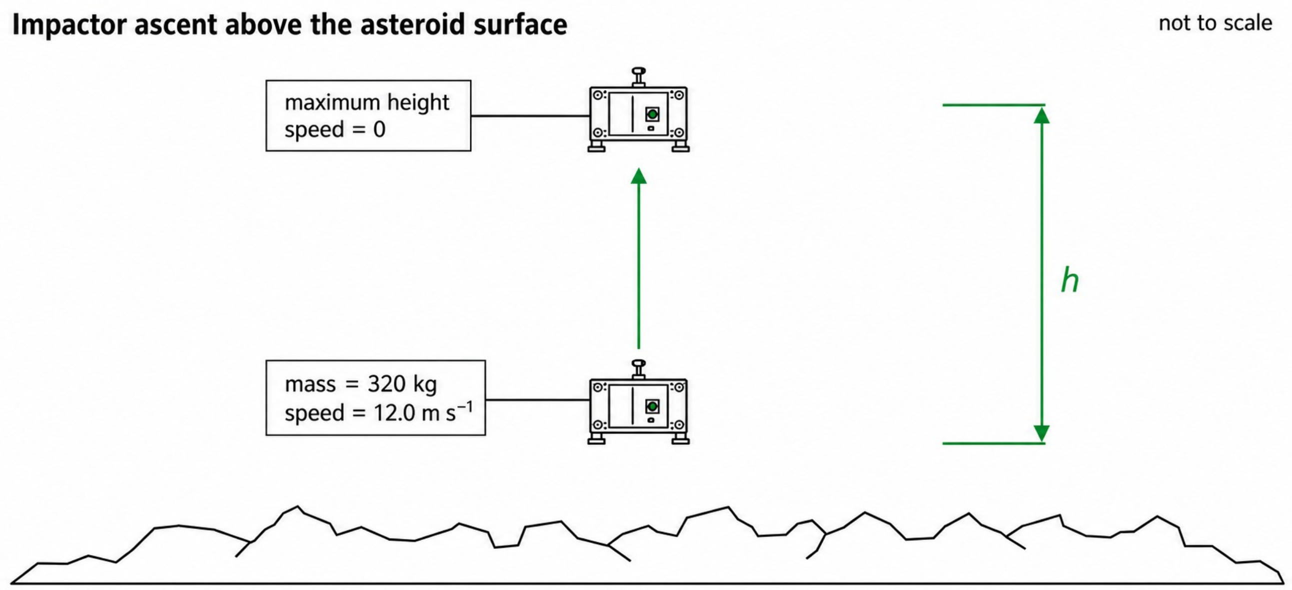
(a) A 24.0 kg mapping drone moves at 6.50 m s⁻¹. Calculate its kinetic energy. **[2 marks]**

(b) A 27.0 kg inspection unit has kinetic energy 864 J. Calculate its speed. **[2 marks]**

(c) An 18.0 kg instrument is lifted vertically through 75.0 m. Calculate its increase in gravitational potential energy. **[1 mark]**

3. A complete energy transfer [4 marks]

A 320 kg kinetic impactor fires its thrusters close to the asteroid surface until it is moving vertically upwards at 12.0 m s⁻¹. Its engines then switch off. Resistive forces are negligible and g = 0.24 N kg⁻¹ is uniform.



Near the surface, take g = 0.24 N kg^{-1} and ignore resistive forces.

(a) Calculate the impactor's kinetic energy when the engines switch off. **[1 mark]**

(b) Calculate the maximum height reached above the switch-off point. **[2 marks]**

(c) Describe the exchange between kinetic energy and gravitational potential energy as the impactor rises. **[1 mark]**

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4. Does mass affect the maximum height? [3 marks]

Two sample hoppers have different masses. Each leaves the same point at 9.60 m s^{-1}. Resistive forces are negligible and g = 0.24 N kg^{-1}.

(a) State which hopper reaches the greater maximum height. **[1 mark]**

(b) Use the kinetic and gravitational potential energy equations to show that mass cancels, then calculate the maximum height. **[2 marks]**

5. A tethered canister: partial transfer while rising [5 marks]

A 48.0 kg sample canister leaves the surface vertically at 10.0 m s^{-1}. A magnetic brake on its tether transfers energy to thermal stores. At the highest point, 72% of the initial kinetic energy has increased the gravitational potential energy store. Use g = 0.24 N kg^{-1}.

(a) Calculate the initial kinetic energy of the canister. **[1 mark]**

(b) Calculate the increase in gravitational potential energy. **[1 mark]**

(c) Calculate the maximum height reached. **[2 marks]**

(d) Calculate the energy transferred to thermal stores by the brake. **[1 mark]**

6. A landing package: partial transfer while falling [5 marks]

A 90.0 kg seismometer package starts from rest 160 m above its landing site. At touchdown, 65% of the decrease in gravitational potential energy is in the package's kinetic energy store. The remainder has been transferred to thermal and internal energy stores. Use $g = 0.24$ N kg^{-1}.

(a) Calculate the decrease in gravitational potential energy. **[1 mark]**

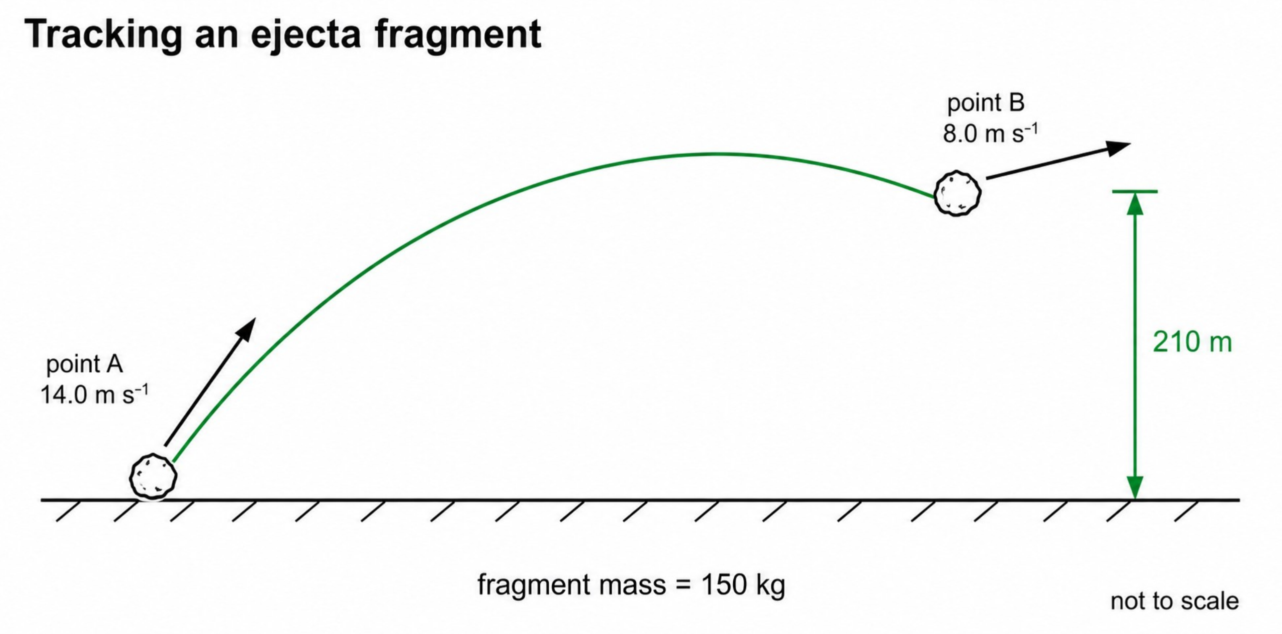
(b) Calculate the kinetic energy at touchdown. **[1 mark]**

(c) Calculate the touchdown speed. **[2 marks]**

(d) Calculate the energy transferred to thermal and internal energy stores. **[1 mark]**

7. Tracking an ejecta fragment [4 marks]

A 150 kg fragment leaves an impact crater at point A with speed 14.0 m s^{-1}. At point B it is 210 m higher and moving at 8.0 m s^{-1}. Use $g = 0.24$ N kg^{-1}.



(a) Calculate the decrease in kinetic energy from A to B. **[1 mark]**

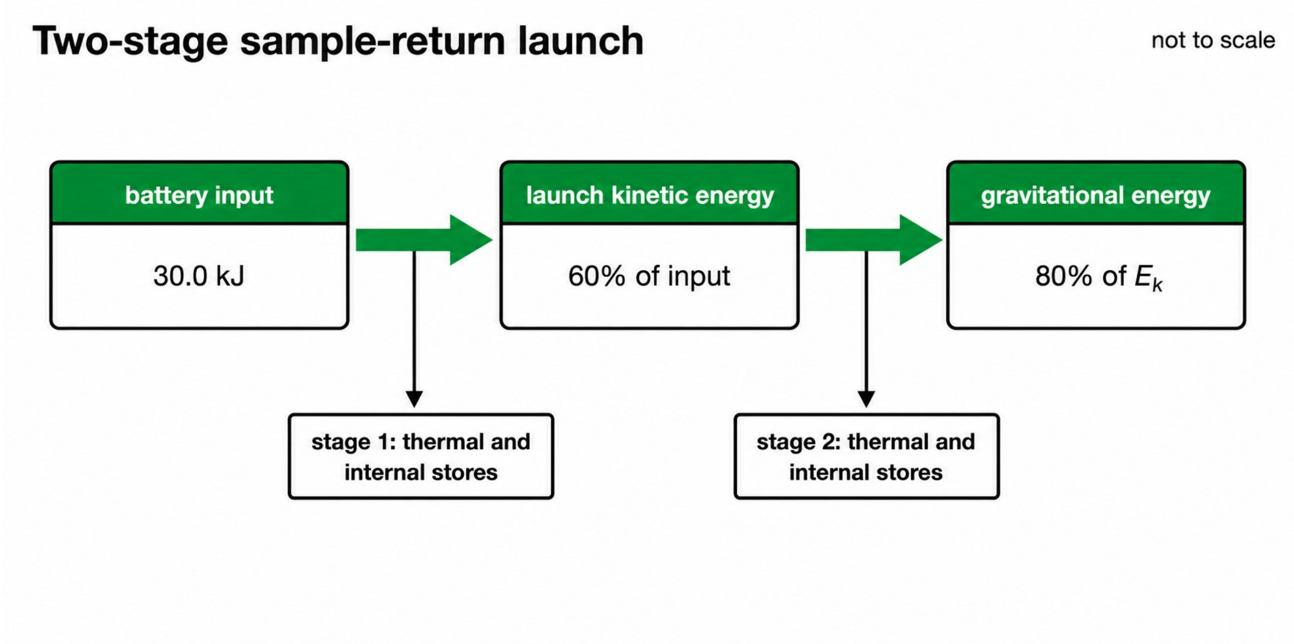
(b) Calculate the increase in gravitational potential energy from A to B. **[1 mark]**

(c) Calculate the energy transferred to other stores between A and B. **[1 mark]**

(d) Explain why the calculation shows that the transfer from kinetic energy to gravitational potential energy is only partial. **[1 mark]**

8. Two-stage sample-return launch [7 marks]

A launcher transfers 30.0 kJ from a battery's chemical energy store. In stage 1, 60% becomes kinetic energy of a 120 kg sample capsule. In stage 2, 80% of that kinetic energy increases the capsule's gravitational potential energy. Use g = 0.24 N kg⁻¹.



(a) Calculate the kinetic energy of the capsule immediately after launch. **[1 mark]**

(b) Calculate the launch speed. **[2 marks]**

(c) Calculate the increase in gravitational potential energy during stage 2. **[1 mark]**

(d) Calculate the height gained during stage 2. **[1 mark]**

(e) Calculate the total energy transferred to thermal and internal energy stores across both stages. **[1 mark]**

(f) Calculate the percentage of the original 30.0 kJ that becomes gravitational potential energy. **[1 mark]**

Review and improve

□ I can derive $E_k = \frac{1}{2}mv^2$ and $\Delta E_p = mg\Delta h$ from earlier mechanics.
□ I can distinguish a complete transfer from a partial transfer.
□ I can account for energy transferred to thermal and internal stores.